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The Investigation of Femtocell Home eNodeB (HeNB) Propagation Path Loss Model

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ABSTRACT

In order to overcome the problem of indoor mobile signal coverage as well as dealing with the signal reception from macro cells, femtocell is introduced. It is installed in a short service range by the subscribers, called as Home evolved Node B (HeNB) [1] There are four carrier frequencies used for Long Term Evolution (LTE), 850MHz, 1800 MHz, 2300MHz, and 2600 MHz. With the changes of criteria of the surrounding such as frequencies, distance, height and surrounding materials, the smaller the path loss value in indoor environment, the better the signal reception will be. Third Generation Partnership Project (3GPP) used TR36.814 with 2 GHz carrier frequency with different lengths and obstructions, however this frequency is not offered for LTE in Malaysia and some studies need to be done in order to find the one with the best signal reception. This resulted on how the number of wall layers play roles in an indoor environment. 850MHz was found out to be the best frequency out of the four LTE frequencies in Malaysia for different types of indoor environment.

Keywords: *Femtocells, Path Loss, LTE, 3GPP.*

1. INTRODUCTION

Recent finding shows that almost 70% of users used mobile phone in an indoor environment [1]. With that, higher data demand was caused by the increasing higher data rates demand and Quality of Services (QoS) of wireless mobile communication [2]. The network operators are forced to provide good service for outdoor and indoor capacity and coverage and low cost is needed through a better mobile system in order to fulfill the demand of higher data as well as the increasing number of users. This also helps to reduce the data traffic caused by the tremendous number of users nowadays [1].

As the mobile communication demand increases the technology evolved to Long Term Evolution (LTE) as the Fourth Generation (4G). It has a low cost service that can deliver a good QoS end to end service with higher speed mobile data [3]. LTE has a wide selection of frequency carrier such as 850 MHz, 1800 MHz, 2300 MHz and 2600 MHz.

Femtocells can be called as small cell used Home eNB (HeNB) as the base station is used to improve signal coverage and at the same time can improve the data and speed rate of the mobile communication. It reduces the cell size as well as increases the data rates similar to the

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Macro eNB but with a lower price that can serve smaller range of user and low transmitting power [1]. In order to find the best carrier frequency out of the four LTE frequencies used in the materials of the walls, the penetrated floors, the wall thickness and also the distance of user [4], need to be considered. The path loss of the surroundings do play an important role towards finding the best frequency in order to increase the data and speed rate.

A research from 3GPP TR36.814 made a similar approach of fulfilling the demand [4]. Unfortunately, the model only used 2GHz carrier frequency in order to fulfill the equation and results. It does not comply with the LTE frequency that is used in Malaysia. There is no other research focusing on other carrier frequency especially in the femtocell area. This study and research will provide useful information particularly in determining the best frequency that can be used in Malaysia with the smallest value of path loss. By using the 3GPP TR 36.814 research model, it will try to identify the power of radio wave signal from the base station HeNB within the distance including the wall penetration loss.

2. LITERATURE REVIEW

2.1 Mobile Technology

The rapid growth of mobile evolution causes the increase of mobile devices and data rates. From 0 Generation (0G) or to be called as pre-cellular phone to wireless, the mobile evolution has been growing big [5]. The First Generation (1G) features a voice only communications by using analog traffic channels and Frequency Dimension Multiple Access (FDMA) for multiple access plays [5][3]. The only limitation in this generation is for its less security [6]. Second Generation (2G) uses digital systems for short messages and small speed data [3]. In this generation, the capacity, services and data rates improve despite the less support of internet [6]. Third Generation (3G), support high speed wireless communication with the use of Universal Mobile Telecommunication System – High Speed Packet Access A(UMTS)-(HSPA) and CDMA2000 EV-DO and also WiMAX [5][3]. Fourth Generation (4G), where IP-based environment is being used in all telecommunications requirement either in wireless or fixed network was also created in order to solve all the remaining problems from 3G such as providing variety of new services, high quality of video and voice and also higher data rate for wireless channel [5].

2.2 Cells

Femtocell is designed to improve the coverage in an indoor environment known as small cell where it increases the capacity when user’s demand is high, improves the performance and quality of the service and also increases the bitrate per unit area. It also covers up the area that the macro network did not manage to cover [7]. Femtocell is created especially for indoor usage in order to increase the capacity and coverage [8]. It resembles a Wi-Fi access point where it has its own wired backhaul connection connected, small in size, lower cost and power consuming [9]. It is very rapidly used as it is estimated that over 50 million femtocells were deployed globally by 2014 [9].

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2.3 3GPP Technical Report TR36.814

TR36.814 is a research project released by 3rd Generation Partnership Project (3GPP) where it compared the benefits of each technique after describing the potential of physical layer of evolution and the complexity of each technique [4]. The technical report model is basically based on Okumura-Hata, COST 231 model and free space propagation path loss model where the distance and frequency are the important elements in the equation. In TR 36.814, the femtocell was used in indoor femto channel models (dual strip model) at a suburban place. They used a 2GHz frequency and the equation used for the study as follows [4] :

$$\mathrm{PL\ (dB)} = 38.46 + 20\log \mathrm{R} + 0.7\mathrm{d} + 18.3\mathrm{n}^{[(\mathrm{n}+2)/[(\mathrm{n}+1)-0.46]]} + \mathrm{q} * \mathrm{L_{iw}} \quad (1)$$

Where:

- **38.46 + 20 log R** :Free Space Path Loss in unit dB where R stand for distance in unit m between the user and broadband. (TR36.814 uses frequency of 2GHz [4].)
- **d** : Loss due to internal walls in unit m (TR36.814 uses log linear value that is equal to 0.7dB/m [4].)
- **n**: number of penetrated floors.
- **q** : number of walls
- $\boldsymbol{L_{iw}}$: Penetration loss of the wall separating apartments (TR36.814 uses the value of 5dB [4].)

3. METHODOLOGY

3.1 Wall Material

The type of wall material that will be used are bricks as it is a common materials to be used for residential. The thickness that will be implied is 4.5 inches that is 0.11m. The penetration loss of the wall separating apartments, L_{iw} is 5dB and the loss due to internal walls, d is 0.7dB/meter [4].

,The Delima 2nd floor Residence is selected to find the best frequency within all the path loss of the surrounding. The situation that will be implied is shown in Figure 1.

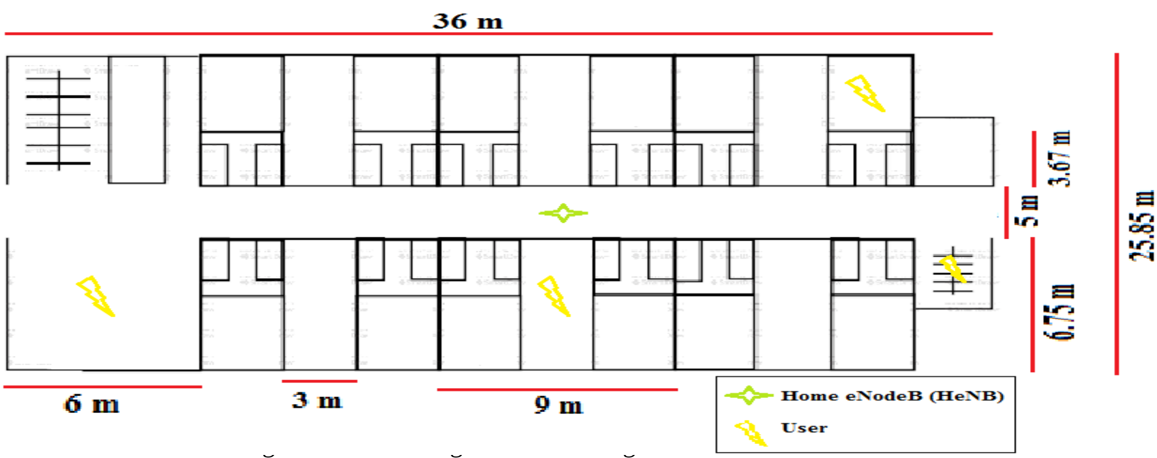

Figure 1. University Technology Mara, Pulau Pinang's College Residence, Delima 2nd floor, floor plan.

The HeNB wass placed in the middle of the hallway between six houses. The users then were placed at the stairs, lift corridor, a rest area and a bedroom in one of the houses. The distance between the HeNB and users and also the number walls the signal frequency propagate through are stated in Table 1.

TABLE 1: Distance and number of walls for every location.

Location	Distance (m)	Number of Walls
Stairs	15.61	7
Lift	18.21	6
Rest Area	7.71	1
Bedroom	14.26	6

3.2 Equation

Equation (1) will be used as the main equation. It is adapted from the technical report paper of 3GPP, TR36.814. As there are four frequencies 850MHz, 1800 MHz, 2300MHz, and 2600 MHz and four types of situation that will be used, the equation will vary from one characteristic to another. The equations are tabulated in Table 2.

TABLE 2: The derived propagation path loss for different frequency bands.

Frequency	Equation
850 MHz	$\mathrm{PL\,(dB)} = 31.03 + 20\log R + 0.7d + 18.3n^{[(n+2)/[(n+1)-0.46]]} + q * L_{iw}$
1800 MHz	$\mathrm{PL\,(dB)} = 37.54 + 20\log R + 0.7d + 18.3n^{[(n+2)/[(n+1)-0.46]]} + q * L_{iw}$
2300 MHz	$\mathrm{PL\,(dB)} = 39.68 + 20\log R + 0.7d + 18.3n^{[(n+2)/[(n+1)-0.46]]} + q * L_{iw}$
2600 MHz	$\mathrm{PL\,(dB)} = 40.74 + 20\log R + 0.7d + 18.3n^{[(n+2)/[(n+1)-0.46]]} + q * L_{iw}$

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Where R is distance in unit between the user and HeNB (0 m to 20 m), d is loss due to internal walls in unit meter (0.7dB/m), then, n is number of penetrated floors, q is number of walls, L_{iw} is the penetration loss of the wall separating apartments (5dB).

4. RESULTS

From Figure 2, the graph stated the result of every frequency's path loss that varies within a 20m distance between the HeNB and the user located at the stairs. It can be seen that the frequency of 850 MHz that did not go through any walls has the smallest value of path loss that is 59.34 dB at the distance of 15.61m. The same goes to the 850MHz frequency that went through 5 layer of walls, as it resulted to be the lowest path loss between all of the frequencies that is 94.34 dB. While, the frequency with the highest path loss, 69.05 dB with no walls and 104.1 dB with 5 walls was 2600MHz.

Even in Figure 3, Figure 4 and Figure 5, by locating the user at the lift corridor, rest area and bedroom in house, where the distance was 18.21m at the lift corridor, 7.71m at the rest area and 14.26m at the bedroom, the frequency of 850 MHz had the lowest path loss while 2600 MHz had the highest path loss. Even the situation where it had to go through numbers of walls, the result trends were almost the same. The comparison can be seen in Table 3, 4, 5 and 6.

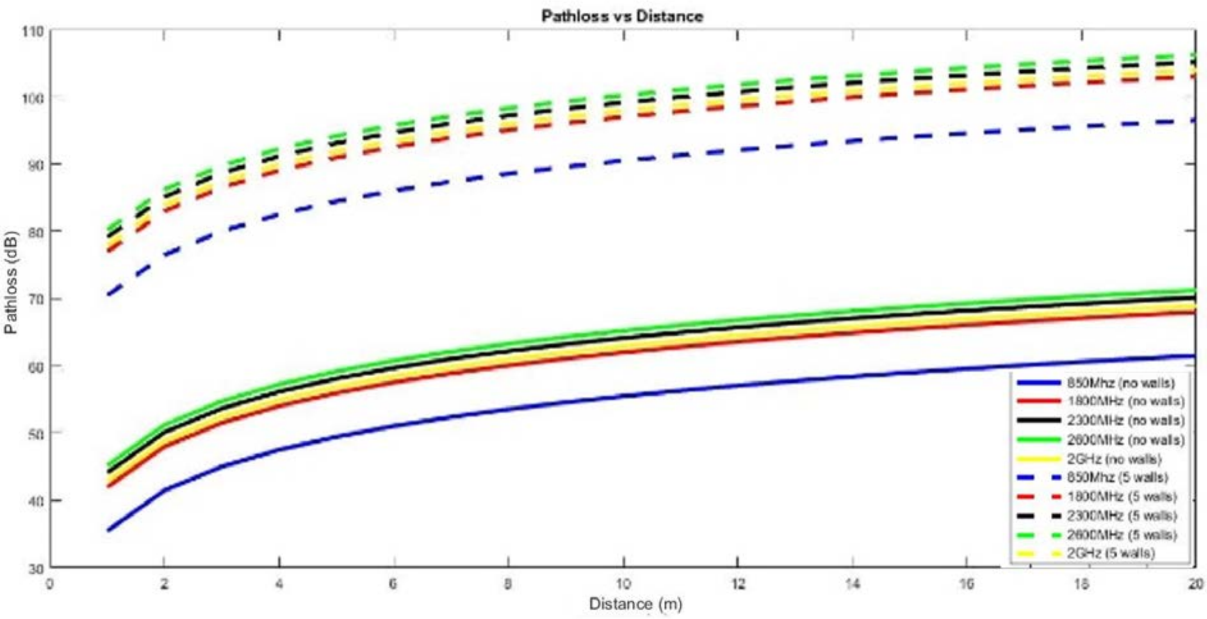

Figure 2: Graph of Path loss versus Distance at stairs

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TABLE 3: Result of path loss at stairs

Location	**Stairs**			
Distance (m)	15.61			
Number of Walls	7			
Frequencies (GHz)	0.85	1.8	2.3	2.6
Path Loss (No walls) (dB)	59.34	65.85	67.99	69.05
Path Loss (With walls) (dB)	94.34	100.9	103	104.1

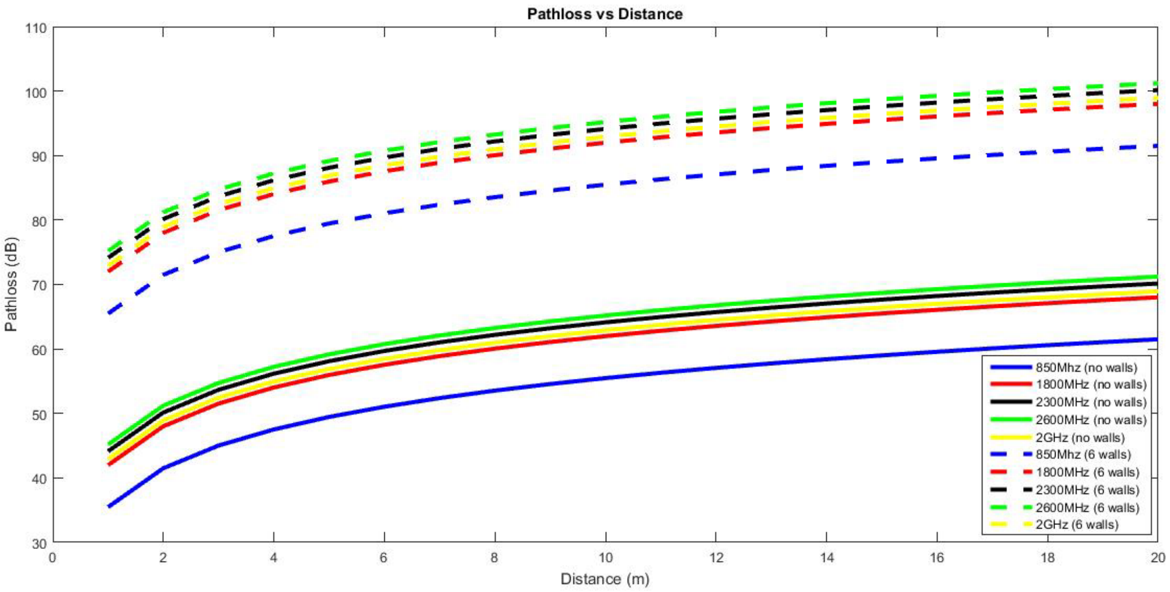
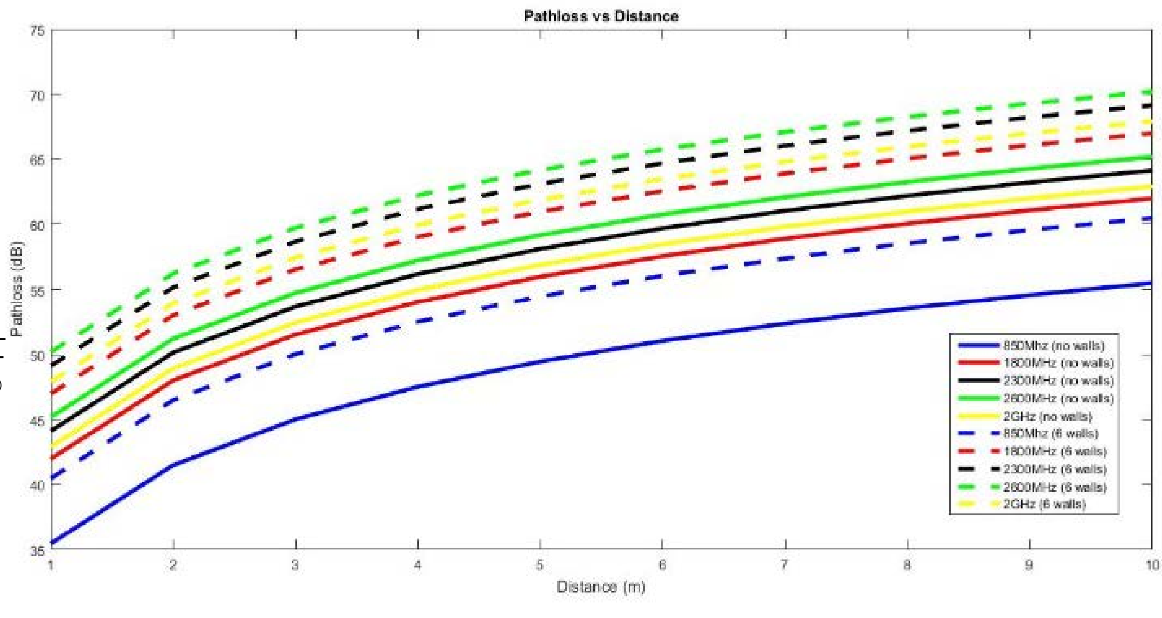


Figure 3: Graph of Path loss versus Distance at lift corridor.

TABLE 4: Result of path loss at lift corridor.

Location	**Lift Corridor**			
Distance (m)	18.21			
Number of Walls	6			
Frequencies (GHz)	0.85	1.8	2.3	2.6



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Path Loss (No walls) (dB)	60.69	67.2	69.33	70.39
Path Loss (With walls) (dB)	90.69	97.2	99.3	100.4

Figure 4: Graph of Path loss versus Distance at rest area.

TABLE 5: Result of path loss at rest area.

Location	**Rest Area**			
Distance (m)	7.71			
Number of Walls	1			
Frequencies (GHz)	0.85	1.8	2.3	2.6
Path Loss (No walls) (dB)	53.21	59.72	61.87	62.93
Path Loss (With walls) (dB)	58.21	64.72	66.86	67.92

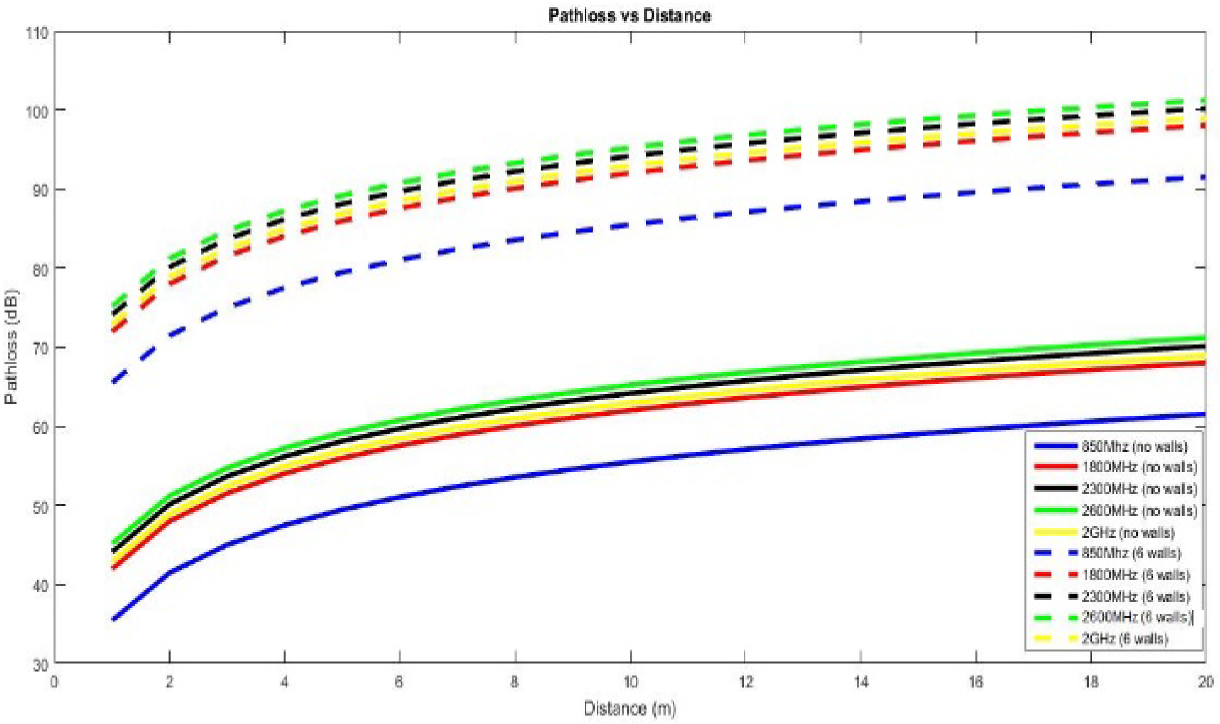

Figure 5: Graph of Path loss versus Distance at bedroom.

TABLE 6: Result of path loss at bedroom.

Location	**Bedroom**			
Distance (m)	14.26			
Number of Walls	6			
Frequencies (GHz)	0.85	1.8	2.3	2.6
Path Loss (No walls) (dB)	58.56	65.07	67.21	68.27
Path Loss (With walls) (dB)	88.56	95.07	97.21	98.27

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Therefore, from this study, it can be finalized that the frequency of 850MHz of LTE is the most suitable frequency to be used in Malaysia in an indoor environment as it has the lowest path loss value throughout distance and numbers of walls.

5. CONCLUSION

In conclusion, the purpose of this project is to find the best frequency out of the four LTE frequency in Malaysia in different types of indoor environment. The different environment will have either less of more loss from the material and object surrounding the indoor environment. Among the selected carrier frequencies the 850 MHz showed the best performance compared to others. Therefore, the objective of this project can be widened if more thorough research is conducted employing different numbers of indoor environment with different material and object surrounding it. More importantly, by using the femtocell Home evolved NodeB (HeNB) base station, this can help ensure that the frequency chosen is the best frequency to meet up with the increasing capacity and users' demands especially in the indoor environment.

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